



LITERATURE REVIEW

A diagnostic test for malnutrition in adults: mid-upper arm circumference towards body mass index: A literature review

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Abstract

Body mass index is commonly used for detecting malnutrition. At certain conditions, body mass index cannot be measured, so mid-upper arm circumference can be an alternative measurement for detecting malnutrition. Several studies have proposed the cut-off point of mid-upper arm circumference in adults along with its sensitivity, specificity, and area under the ROC curve (AUC). This article aims to describe the diagnostic test for malnutrition using the upper arm circumference in adults and summarize the results of the related studies.

Keywords BMI, diagnostic test, malnutrition, MUAC

Introduction

Nutritional status is defined as a body condition that is the result of a balance of intake, absorption, use of nutrients that can affect physiological and pathological conditions.¹ If for any reason, such as insufficient intake, increased demand for nutrients, or a disorder in the absorption/use of nutrients, there is a negative balance, then undernutrition/malnutrition develops.² Malnutrition is assessed based on an assessment of food intake, laboratory tests, anthropometric measurements, and clinical observation. Anthropometric measurements involve measuring physical dimensions and body composition, the results can be vary depending on age, sex, race, and nutritional status. This measurement is often used to assess energy and protein imbalances, as well as to assess the degree of

malnutrition, but cannot explain a specific nutrient deficiency.³ Some anthropometric measurement methods used to assess nutritional status are body mass index (BMI) and mid-upper arm circumference (MUAC). In certain conditions, it can be difficult to perform height and weight measurements to calculate BMI.⁴ Mid-upper arm circumference can be an alternative measurement for undernutrition screening. To date, there was no valid cut-off point for mid-upper arm circumference in adults as in children. This article aims to describe the diagnostic test for malnutrition using the mid-upper arm circumference in adults and summarize the results of the related studies.

Body mass index

Body mass index was first described by Adolph Quetelet in 1835, so it is also called the Quetelet index.⁵ BMI is defined as body weight in kilograms divided by the square of height in meters.^{3,5} It is a commonly used measurement for assessing nutritional status quickly, easily, and non-invasively.³

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The body mass index has some limitations, it cannot differentiate between body weight due to fat mass or fat-free mass. BMI values can be high due to excess fat mass, muscle mass (for example in athletes), or edema.^{1,3} In certain circumstances, BMI is difficult to assess, for example, if the patient is unable to stand or conditions that affect height measurements such as kyphosis, compression fractures vertebral due to osteoporosis, or scoliosis.⁶ The World Health Organization (WHO) established the BMI cut-off value for assessing nutritional status by relating it to morbidity and mortality. BMI <18.5 kg/m² is categorized as undernutrition/malnutrition.

Mid-upper arm circumference

The measurement of the MUAC is made at the midpoint between the acromion and olecranon. MUAC is consist of subcutaneous fat and muscle, so any changes in MUAC can represent changes in muscle mass, subcutaneous fat mass, or both. In malnourished patients who tend to have low subcutaneous fat, changes in MUAC are more representative of changes in muscle mass. Measuring MUAC is easy, fast, and only uses a simple tool (measuring tape).³ MUAC measurement can be performed in patients who cannot stand because it can be taken in a lying position. There was no significant difference between measurements of upper arm circumference in standing and lying positions (p-value = 0.855).⁷

In the measurement in a standing position, the subject stands with feet together and arms bent 90 degrees at the elbows with palms facing up. The examiner stands behind the subject and looks for the acromion process of the scapula. Then the examiner holds the end of the measuring tape at the acromion and pulls it up to the olecranon. After that, the examiner holds the measuring tape in that position and marks the midpoint between the acromion and olecranon. Subjects were asked to straighten their hands then the measuring tape was looped on the marked point and measured in the nearest millimeter.⁸ For more details see **Figure 1**.

Several studies have been conducted to assess the usefulness of measuring the MUAC.^{9–12} McMillan et al.⁹ assessed the influence of several variables (BMI, weight loss, skinfold thickness, MUAC, albumin, C-reactive protein, and cancer type and

stage) on Karnofsky performance status in 148 advanced gastrointestinal cancer patients. From multiple regression analyzes, only MUAC and log₁₀ C-reactive protein ($R^2 = 0.462$, $P < 0.0001$) in men and only MUAC and weight loss in women ($R^2 = 0.485$, $P < 0.01$) as an independent predictor of Karnofsky performance status.⁹

MUAC is inversely related to the risk of all-cause mortality.^{10,11} Higher MUAC with normal BMI has a low risk of mortality.¹⁰ Whereas low MUAC has a statistically significant relationship with increased risk of mortality in the elderly that is stronger than with low BMI and calf circumference.¹²

A diagnostic test for malnutrition

Assessing the validity of screening tools is one of the goals of diagnostic tests. Besides, diagnostic tests also aim to establish a diagnosis of disease, for patient treatment, and epidemiological studies. The basic principle of a diagnostic test is to find a new diagnostic test that has several advantages over the previous diagnostic test. Some of them are that the diagnostic value is not much different, it is not invasive, easier to use, and cheaper.¹³

The validity of an instrument with a nominal scale can be assessed by comparing it with the best available diagnostic tool (gold standard). BMI is used as the gold standard in this diagnostic test. MUAC meets the basic principle of a diagnostic test because MUAC does not require expensive equipment, easy to perform, and not invasive. MUAC can be used to assess nutritional status if MUAC has high sensitivity (a slight possibility for false negative) and fair specificity.¹³ Information obtained from the diagnostic test of MUAC towards BMI is presented in **Table 1**.

Receiver operating characteristic (ROC) curve of MUAC towards BMI

The receiver operating characteristic (ROC) curve is a graph that presents the bargaining between sensitivity and specificity to determine the cut-off point of MUAC towards BMI.¹³ The Y coordinate is the sensitivity against the false positive (1-specificity) value as the X coordinate. The cut-off point of MUAC is determined based on the highest

sensitivity and specificity or the highest Youden's index (sensitivity + specificity – 1).¹⁵

Diagnostic test performance can be assessed by calculating the area under the ROC curve (AUC). An AUC values range from 0 to 1, the closer to number 1 the better the diagnostic test. An AUC value equal to 1 represents a perfect diagnostic test, which is very accurate in distinguishing between malnutrition or not.^{15,16} The categories used to summarize accuracy of AUC in ROC analysis were as follows: AUC of 0.9–1 (excellent), 0.8–0.9 (good), 0.7–0.8 (fair), 0.6–0.7 (poor) and 0.5–0.6 (fail). A test with an AUC ≥ 0.85 is generally considered as an accurate test.¹⁷

Research about MUAC cut-off point for detecting malnutrition

Various studies have shown a significant correlation between MUAC and BMI, it is known that individuals with low MUAC are likely to have a low BMI.^{4,6,18–23} Research conducted by Brito et al.⁸ on 1373 inpatients at a hospital in Spain, showed that there was a correlation between BMI and MUAC with $r = 0.78$ ($p < 0.001$). The cut-off point value for detecting malnutrition obtained from this study was 22.5 cm for both men and women. This study also obtained a regression equation to find BMI, that is $0.042 + 0.873 \times \text{MUAC (cm)}$ ($R^2 = 0.609$). Tuck and Henessy¹⁹ also developed a regression equation to determine the BMI from MUAC. For males: $\text{BMI} = 1.01 \times \text{upper arm circumference} - 4.7$ ($R^2 = 0.76$) and for women: $\text{BMI} = 1.10 \times \text{upper arm circumference} - 6.7$ ($R^2 = 0.76$).¹⁹ This equation has been validated in the study of Barosa et al.²⁴

Food and Nutrition Technical Assistance III Project (FANTA) conducted a meta-analysis regarding the sensitivity and specificity of various

cut-off points for MUAC in adults (men and women who were not pregnant) to identify malnutrition measured by $\text{BMI} < 18.5 \text{ kg/m}^2$. This study suggested that MUAC in the range of ≤ 23.0 to ≤ 25.5 cm can be used as an indicator of low BMI ($\text{BMI} < 18.5 \text{ kg/m}^2$), with acceptable sensitivity and specificity values. The cut-off point of MUAC ≤ 24.0 cm was chosen for reasons of optimal sensitivity and specificity.⁴

Several proposed cut-off points of MUAC for detecting malnutrition along with its sensitivity, specificity, and AUC was summarized in **Table 2**. The cut-off point of MUAC may be varied due to differences in body composition among different races, especially the distribution of body fat, which may be not adequately captured by measures of overall adiposities (BMI) when compared to MUAC, which measures regional adiposity. The higher cut-off point might be more accurate in Asian populations that have a higher proportion of body fat than other races (e.g., Caucasians and Africans).²⁵ Overall, the sensitivity, specificity, and AUC of MUAC towards BMI is good enough, so MUAC can be used for detecting malnutrition.

Conclusion

Since the sensitivity, specificity, and AUC of MUAC is good, it can be an alternative measurement for detecting malnutrition in adults, particularly in a community setting or low-resource setting. It can also be used in a hospital setting when BMI cannot be measured. There was no valid cut-off point of MUAC that can be used in all population. populations. Further research needs to validate this cut-off point.

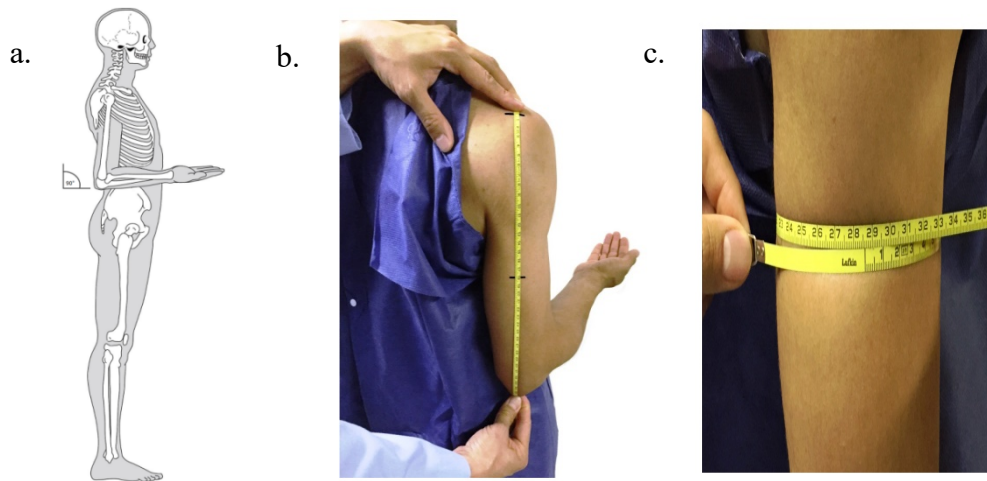


Figure 1. MUAC measurement in a standing position

a. Standing position of the subject b. Position the tape correctly and mark the midpoint of the upper arm. c. Measure the circumference of the mid-upper arm

Source: reference number 8

Table 1. 2x2 table for MUAC and BMI

		Malnutrition (measured by BMI)		Total
		BMI < 18.5 kg/m ²	BMI ≥ 18.5 kg/m ²	
MUAC	< cut-off point	True positive (a)	False positive (b)	a+b
	≥ cut-off point	False negative (c)	True negative (d)	c+d
Total		a+c	b+d	a+b+c+d

From the table above can be assessed sensitivity, specificity, positive predictive value, and negative predictive value:

- Sensitivity = $a / (a + c)$.
- Specificity = $d / (b + d)$.
- Positive predictive value = $a / (a + b)$.
- Negative predictive value = $d / (c + d)$.^{4,14}

Table 2. The cut-off point of MUAC from various studies for detecting malnutrition

Researcher	Subject	Total subject	MUAC cut-off point (cm)	Sen	Sp	AUC
Brito et al. ⁶	Inpatient, Spain	1373 subjects	22.5	67.7	94.5	0.92
van Tonder et al. ¹⁸	Inpatient, South Africa	86 males	23.7	86.4	78.6	0.88
		80 females	23.5	93.1	100	0.98
Goswami et al. ²⁰	Elderly, India	267 males	25.7	80.2	78.6	0.85
		259 females	24.3	79	79	0.86
Das et al. ²²	Adults slum dwellers, India	467 males	22.7	85.71	74.8	0.85
		488 females	21.9	91.67	79.89	0.93
Sultana et al. ²¹	Inpatient, Bangladesh	260 males	25.1	92.6	79.4	0.814
		390 females	23.9	92.6	76.6	0.882
Thorup et al. ²³	Urban public hospitals, Nepal	302 subjects	24.5	92.86	82.48	0.94
FANTA-III ⁴	A meta-analysis from 17 studies with various population	-	24	81.9	85.6	-

Sen: sensitivity; Sp: specificity; AUC: area under the ROC curve

Conflict of Interest

Authors declared no conflict of interest regarding this article.

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